PB81-166720

Light Duty Vehicle Fuel Economy Labeling

(U.S.) Environmental Protection Agency
Ann Arbor, MI

Oct 80

U.S. Department of Commerce
National Technical Information Service
NTIS.

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
EPA-AA-CTAB-FE-81-6		PB81 166720

4. TITLE AND SUBTITLE	5. REPORT DATE
Light Duty Vehicle Fuel Economy Labeling	October 1980
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) none given	8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Environmental Protection Agency Office of Mobile Source Air Pollution Control Emission Control Technology Division Ann Arbor, Michigan 48105	10. PROGRAM ELEMENT NO. 11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS Same.	13. TYPE OF REPORT AND PERIOD COVERED Technical 14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

EPA is initiating rulemaking proceedings to upgrade certain aspects of the EPA/DOE Fuel Economy Information Program. This report provides technical input to those rulemaking proposals. The results of five surveys of consumers' opinions on fuel economy, and on various vintages of the fuel economy information program, are summarized. They indicate a general credibility problem with the current EPA fuel economy figures.

Design parameter sensitivity algorithms are presented, and the need is established for their use in deriving fuel economy ratings for untested vehicles.

Road adjustment factors developed from recent in-use fuel economy survey data are given for a number of different labeling strategies, and the strategies compared and contrasted.

Results of a detailed analysis of the effects on label "accuracy" of inclusion/exclusion of road adjustment factors and varying levels of vehicle-specificity in labeling are given. From this study, the incremental benefit of progressive levels of departure from the current (1981) model type labeling system can be estimated.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Automobiles Fuel Consumption Labels Marking	Light-duty Vehicless Fuel economy	

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS (This Report)	21. NO. OF PAGES
Release unlimited	Unclassified	47 p.
	20. SECURITY CLASS (This page) Unclassified	22. PRICE

EPA Form 2220-1 (9-73)

PB81-166720

EPA/AA/CTAB/FE-81-6

Technical Support Report for Regulatory Action

Light Duty Vehicle Fuel Economy Labeling

October, 1980

Notice

Technical support reports for regulatory action do not necessarily represent the final EPA decision on regulatory issues. They are intended to present a technical analysis of issues and recommendations resulting from the assumptions and constraints of that analysis. Agency policy constraints or data received subsequent to the date of release of this report may alter the recommendations reached. Readers are cautioned to seek the latest analysis from EPA before using the information contained herein.

Control Technology Assessment and Characterization Branch
Emission Control Technology Division
Office of Mobile Source Air Pollution Control
Office of Air, Noise and Radiation
U.S. Environmental Protection Agency
2565 Plymouth Road
Ann Arbor, Michigan 48105

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA 22161

ERRATUM

EPA/AA/CTAB/FE-81-6

Page 38, Line 11 should be:

```
TH(X1,X2,D,F2)=D+(F2*2*S*(X1-X2))/(X1+X2+S*(X1-X2))
```

or its equivalent

```
TH(X1,X2,D,F2)=D-(F2*2*S*(X2-X1))/(X1+X2-S*(X2-X1))
```

ABSTRACT

In response to the Congressional concerns which mandated the EPA "Section 404 Report", and which motivated the "Moffett Hearings", EPA is initiating rulemaking proceedings to upgrade certain aspects of the EPA/DOE Fuel Economy Information Program. This report provides technical input to those rulemaking proposals.

The results of five surveys of consumers' opinions on fuel economy, and on various vintages of the fuel economy information program, are summarized. They indicate a general credibility problem with the current EPA fuel economy figures.

Design parameter sensitivity algorithms are presented, and the need is established for their use in deriving fuel economy ratings for untested vehicles.

Road adjustment factors developed from recent in-use fuel economy survey data are given for a number of different labeling strategies, and the strategies compared and contrasted.

Results of a detailed analysis of the effects on label "accuracy" of inclusion/ exclusion of road adjustment factors and varying levels of vehicle-specificity in labeling are given. From this study, the incremental benefit of progressive levels of departure from the current (1981) model type labeling system can be estimated.

I. BACKGROUND

In 1978, Congress recognized that there was a discrepancy between EPA fuel economy numbers and actual consumer in-use experience with fuel economy, and mandated a detailed EPA investigation under Section 404 of the National Energy Conservation Policy Act of 1978. EPA's "404 Report"[1]* is the response to that mandate. That report constitutes an initial technical basis upon which to develop new labeling rulemakings and Gas Mileage Guide protocols for the 1982 models.

In February 1980, a set of hearings, known as the "Moffett Hearings" concerning "Automotive Fuel Economy", were conducted by the U.S. House of Representatives Subcommittee on Environment, Energy and National Resources. One of the recommendations in the hearings report[2] by the Subcommittee was:

> "EPA devise a new MPG system for labeling new cars and for the Gas Mileage Guide that provides fuel economy values, or a range of values, that most drivers can reasonably expect to experience".

II. PURPOSE

In response to the above-mentioned Congressional concerns, EPA has initiated rulemaking proceedings to upgrade certain aspects of the Fuel Economy Information Program. This Technical Report provides additional technical backup to that process, beyond that of the 404 Report, by concentrating on specific issues being addressed in the rulemaking.

---

* Superscripts indicate references, listed at the end of the text.

III. DISCUSSION

In this, the body of this report, four areas of discussion are presented:

A. General evaluation of the Label/Guide system:

Prior to discussions of specific technical analysis aimed at modified fuel economy label figures, this section reviews survey-type information on public awareness and credibility of the Fuel Economy Information Program in recent years;

B. Design parameter sensitivity:

This summarizes the technical analysis leading to equations which account for the fuel economy effects of difference in vehicle weight, axle ratio, and road load horsepower;

C. Road MPG factors:

This summarizes the technical analysis which defines and evaluates labeling strategies and develops road adjustment factors for those strategies;

D. Adjusted labeling:

Using the 1980 fuel economy data base, this example analysis shows how various options for methods of labeling affect distributions of label values.

A. General Evaluation of Label/Guide System

1. Data Sources

The sources of data used in evaluating the Federal Fuel Economy Information Program, both Fuel Economy Labels and the Federal Gas Mileage Guide, were as follows:

a. ABT Telephone Survey[3] - A survey conducted among approximately 600 people nationwide, using a questionnaire-type prompt list to gauge their opinions on fuel economy and related subjects. The respondents were all purchasers of 1976 vehicles. The survey was conducted in February 1976 under FEA (now DOE) sponsorship.

b. EPA Focus Groups[4] - To support the 1979 rulemaking, group discussions were conducted for EPA by Porter and Novelli Associates in three cities (Philadelphia, Pa., New Orleans, La., and Van Nuys, Ca.), utilizing two groups per city, 7-12 people per group (50% women, 50% men). Total number of participants was approximately 60 people. The participants were either purchasers or potential purchasers of new vehicles. The focus group discussions were conducted prior to March 1978.

c. J.D. Power Focus Groups[5] - Focus Group discussions in 17 cities were conducted for DOE by the J.D. Power organization. There were approximately nine people per group, with two (2) groups for 13 cities and one group for four cities, resulting in a total of 30 groups and 246 people. The respondents were all purchasers of new vehicles for model year 1979.

d. J.D. Power Questionaire Survey[6] - For both MY 1978 and MY 1979, questionaire surveys on the Federal Fuel Economy Information Program were conducted for DOE by J.D. Power. The survey was a nationwide random sample of approximately 4000 new car car buyers and 1000 new truck buyers in each of the two model years noted. The MY 1978 survey was conducted in January 1979. The MY 1979 survey was conducted in March 1979 with a further follow-up in June 1979. This technical support report deals only with the 1978 and March 1979 surveys.

e. N.Y. Times Auto Industry Outlook[7] - A survey conducted on its own initiative by the N.Y. Times in April 1980 of both consumers and automobile dealers in regard to automotive attitudes, behavior, and buying plans. There were approximately 1000 consumers and 200 dealerships queried in this marketing survey.

2. Analysis/Summary

A summary of the outputs from each of the previously noted data sources follows; results related specifically to the Fuel Economy Label Program and the Gas Mileage Guide are emphasized.

a. ABT Telephone Survey

Importance of Fuel Economy - 50% of new vehicle buyers considered good fuel economy an extremely important parameter in their vehicle purchase decision. 16% considered it the single most important factor.

Fuel Economy Label Awareness - 53% of the respondents actually saw the label on the vehicle they bought.

Guide Awareness - Awareness of the Guide was very low with only 9% of the buyers indicating awareness of this publication.

Credibility of Gas Mileage Estimates - 64% of "Label aware" buyers did not believe the estimates.

Actual Gas Mileage - Buyers' actual gas mileage averaged about 1 mpg less than the EPA combined estimate.

b. EPA Focus Groups

Representation of Fuel Economy Values - Most participants in the focus groups indicated that single point estimates, regardless of driving mode represented, were misleading. An approach which would convey fuel economy as a range, rather than a point, was deemed most suitable.

Label Information - Information such as range of fuel economy for comparable vehicles, annual fuel costs, and combined fuel economy estimate were deemed confusing by most participants in the focus group studies. Ironically, the first two items are mandated by law.

Gas Mileage Guide - Few participants knew how EPA tested cars; few had ever seen the Guide.

c. J. D. Power Focus Groups

Credibility of EPA Fuel Economy Figures - In general a lack of credibility was apparent among most participants; however, some "well informed" buyers were aware of the comparative nature of the figures and of their application when making a purchase decision.

Fuel Economy Importance - Fuel economy was a very important factor for the vast majority of new car purchasers surveyed. The dominant theme throughout the focus group discussions was that fuel economy was a major factor in vehicle choice.

Desired Content of Label - Most respondents indicated that "more accurate" fuel economy numbers should be displayed. Specifically, 44% preferred a two-number label, with the numbers representing city and highway driving modes; 22% preferred two numbers representing a range within which most drivers would fit; 22% preferred three numbers. Only 12% of the participants indicated a preference for a one-number fuel economy information system.

Availability of Guide - Most respondents indicated that the biggest problem with the Guide was its lack of availability.

d. J. D. Power Questionnaire Survey

Since this survey represents the most extensive data collection performed, the output is the most detailed. The following discussion has two parts: one dealing with the entire survey, with both model years pooled, and one which compares the two model years' results, highlighting possible differences between 1978's three-number information system and 1979's one-number system.

(1). Analysis of J.D. Power Survey (Combined MY78 & 79)

Selection Factor In Buying a Vehicle - Although fuel economy ranked uppermost in people's choices of vehicle selection factors, EPA gas mileage figures ranked 8th in importance. As to general, rather than relative, importance, 64% rated "Fuel Economy" important, while 53% rated "EPA Mileage Figures" important.

Sources of Information on Gas Mileage - The EPA label was rated the most popular and most important item in terms of sources of information; the Gas Mileage Guide ranked 8th. J.D. Power suggests that people associate the label with fuel economy and since it is readily available (prominently displayed) it comes to mind. Since the Guide is not readly available and/or prominently displayed, it does not come to mind as readily as the label.

Awareness of Gas Mileage Guide - Approximately 4 out of 5 respondents were not even aware that there was a Gas Mileage Guide.

Consulting of EPA Booklet - Only 1/3 of the people aware of the Guide actually consulted it.

Selection or Elimination of Vehicle Based on Guide - Only 1/3 of the people who did consult the Guide used the fuel economy information as a criterion to select or eliminate a vehicle.

Why is Label Not Useful - Most car and truck buyers who felt the label was not useful felt so because indicated EPA figures were inaccurate, unrealistic, non-representative.

Attitude Toward Fuel Shortage - Only half the respondents indicated they believed there was a fuel shortage. (Note - these responses were obtained prior to the 1979 fuel shortage.)

55 MPH Speed Limit - 60% of the respondents indicated they believed the 55 MPH limit would save fuel, but only 48% felt it should be vigorously enforced.

Government Mandate to Build Fuel-Efficient Vehicles - Approximately 3/4 of the respondents indicated the Government should require the manufacture of fuel-efficient vehicles.

Driving Style Affects Gas Mileage - The respondents agreed overwhelmingly (90%) that driving style affects fuel economy.

Gas Mileage Record Keeping Practices - Approximately 40% of the respondents indicated they frequently checked gas mileage; another 50% indicated they have some feel for their gas mileage.

Usefulness of the Guide Among Those Who Consulted It - Approximately 55% of the passenger car buyers who were aware of the Guide indicated that the Guide was of some use to them; for truck buyers, the figure was lower, 39%.

Availability of Guide in Auto Dealerships - Only half of the respondents who were aware of the Guide indicated that it was available at the dealerships they visited.

How Did You Locate the Booklet (Guide) - Less than half of those people who obtained Guides got their Guides from dealers.

Awareness of Label on Vehicle - Approximately half of the truck buyers and 1/4 of the car buyers did not recall seeing the fuel economy label on the vehicle.

Use of Label Information for Vehicle Comparisons - Approximately 1/3 of car buyers and 1/5 of truck buyers who were aware of the label used the label information for comparisons.

Usefulness of Label for Purchase Decision - Less than half of label-aware car and truck buyers felt it was of use in their purchase decision.

Knowledge of EPA City Rating for New Vehicles - More than half of the car and truck buyers did not know the EPA city rating for the vehicle they purchased.

Actual Gas Mileage Compared With EPA Rating - Approximately 40% of the respondents indicated that they equaled or bettered their vehicle's EPA city rating. Another 40% achieved MPG lower than the city ratings. With less than half knowing what the EPA ratings were (see previous item), these percentages represent perceived rather than actual results.

Why is Your Mileage Less Than EPA Rating - - Approximately 2/3 of those who felt they achieved less than the ratings stated it was because the EPA figures are overly optimistic; about 1/4 indicated their driving or vehicle/engine may be causes.

EPA Figures Overstate What Owners Get - 60% to 70% of all respondents agreed with this observation.

Why are EPA Figures Overstated - More than half of the respondents who felt the EPA figures were too high blame the EPA test procedures, either as intrinsically unrealistic, or as not being followed.

EPA Figures Serve Useful Purpose for Comparisons - Approximately 2/3 of car and truck buyers did feel that, even though the EPA figures overstated in-use MPG, they were useful for comparison.

(2) Analysis of J.D. Power Survey (1979 versus 1978)

One of the key items which can be inferred from the J.D. Power survey by comparing the model year 1978 & 1979 responses is relative consumer preference for either a single number or a multi-number fuel economy label program. Since no direct questions were included in the survey regarding the "number of numbers", however, this evaluation of consumer preference had to be arrived at by inference from some of the existing questions in the survey. In MY 1978, EPA fuel economy was expressed as a three number system; City, Combined, and Highway. In MY 1979, EPA fuel economy was expressed as a single number system, the City number. In reviewing the Power survey, the following information is pertinent to the "number of numbers" issue*:

Importance of EPA Gas Mileage Figures in New Car Purchase Decision - In 1978, 86% of the respondents indicated EPA figures were important in their purchase decision; in 1979 83% felt that way.

Usefulness of Label Gas Mileage Figures - In 1978, 46% of the respondents indicated EPA figures were useful; in 1979 38% felt that way.

Usefulness of Gas Mileage Guide F.E. Figures - In 1978, 83% of the respondents indicated EPA Gas Mileage Guide figures were useful; in 1979 80% felt that way.

Too Much Information on Label - In 1978, 59% of the respondents indicated the label had too much information; in 1979 63% felt that way.

EPA Gas Mileage Figures Useful for Comparison - In 1978, 76% of the respondents indicated the label figures were useful for comparison; in 1979 72% felt that way.

---

* Reference 8 contains a more extensive evaluation of this issue, including in its appendices much more detail on the survey results than are given here.

EPA Fuel Economy Test Procedure Is Not Representative - In 1978, 17% of the respondents indicated that the EPA fuel economy test procedures were not representative; in 1979 20% felt that way.

Label MPG Should Reflect More Representative Driving - In 1978, 28% of the respondents indicated that the EPA tests should reflect the "real world" to a greater degree; in 1979 35% felt that way.

Considering the directions in which the response percentages moved from 1978 to 1979, it could be concluded that the 1979 system was consistently less satisfactory than the 1978 system. Viewing the statistical insignificance of the generally small numerical differences, however, it can be only concluded that there certainly was no improvement brought about by the change from 1978 to 1979 in the Federal Fuel Economy Program (i.e. from a three number to a one-number system).

According to the ABT survey, in 1976 only 16% of prospective buyers indicated that fuel economy was their primary concern, yet by MY 1980, according to the N.Y. Times survey, 61% of the potential buyers indicated that fuel economy was their primary concern. During this time interval, according to the J.D. Power survey, there was an apparent slight decrease in interest in fuel economy information as reported by the Federal Government. This leads to the conclusion that although people became more interested in fuel economy, they became less interested in Federal Fuel Economy data, and suggests that the change from the three number to the one number system may have had something to do with this loss of interest.

e. New York Times Auto Industry Outlook Market Survey

Importance of Fuel Economy - Fuel economy is the primary concern of 61% of potential new car buyers.

Best Way to Cut Fuel Consumption - Reducing unnecessary driving is the most frequently (27%) mentioned method of reducing fuel consumption by potential new car purchasers.

Sales versus Size - Over half (59%) of the dealers queried indicated increased sales of compacts and sub-compacts while larger sized vehicles showed decreasing sales.

Reason for Depressed Sales of U.S. Autos - Beyond "economic recession" and "price of gasoline", the most often mentioned reason for depressed sales of U.S. autos was "poor gas mileage of American cars".

Government Regulation of Minimum MPG - Over half (54%) of the dealers queried indicated that they opposed government mileage regulations. This question was not asked in the consumer survey.

Sales Message Most Effective in Moving Cars - Emphasis on economy/gas mileage is considered the most effective sales message by dealers (97%) regardless of vehicle type (import or domestic).

3. Conclusions

It is readily apparent that, upon reviewing the results of the aforementioned data sources, fuel economy is a dominant consideration for prospective purchasers of automobiles.

It is interesting to note that in much of the survey and focus group work done prior to the spring of 1979, fuel economy was mentioned as important; but subsequent to the spring of 1979 the importance of fuel economy rose dramatically. It is highly likely that this was due to the cutoff of oil from Iran and the subsequent 60% increase in the cost of gasoline. It is important to note that based upon the latest survey data available to EPA (N.Y. Times), 61% of potential new car purchasers indicated fuel economy as their primary concern in selecting a vehicle for purchase.

There were three areas identified by the focus groups and studies which showed a need for improvements of the Federal Fuel Economy Information Program. These were as follows:

a. Awareness - Time and time again, a majority of respondents indicated that they were not aware of the Gas Mileage Guide. A significant percentage were not even aware of the label, although all of the people surveyed were new vehicles buyers and had presumably visited dealer showrooms.

Since awareness plays such an important role in any information program, it is important that steps be taken to increase the public's awareness of the Federal Fuel Economy Information Program. Some of the actions which EPA could consider are as follows:

(1) Increase the use of media advertising, including television and radio along with the printed medium (e.g. consumer and automotive trade publications).

(2) Use strategically placed signs and billboards in high density locations where a large majority of drivers will be exposed to the Federal Fuel Economy Information Program during the course of their travels.

(3) Work closely with the FTC on fuel economy advertising, including encouragement that the FTC require that all manufacturer ads (in all media) which mention fuel economy indicate availability of the Guide.

b. Availablility - In addition to making the public more aware of the Program, the information output of the Program should be readily available to the public. Some of the actions which could be considered to improve availability are:

(1) Use facilities in high density locations such as service stations, banks, post offices, etc. to distribute the Guide, in addition to new car dealers.

(2) Establish a toll free telephone exchange to disseminate and clarify fuel economy information.

(3) Insert pamphlets concerning fuel economy within popular publications as a "free item" with the magazine.

c. Credibility - Having people aware of fuel economy and having access to such information is not very useful if the information itself is not credible. Therefore to enhance the credibility of the Federal Fuel Economy Information Program the following actions might be considered:

(1) Improve vehicle labeling accuracy (such as would be achieved by going to vehicle-specific fuel economy labels).

(2) Implement a road MPG factor program for fuel economy labels.

Details of the above two programs can be found in subsequent sections of this report.

Implementation of program improvements such as those above, in cooperation with DOE, DOT, FTC, IRS, and GPO, could go a long way toward improving the Fuel Economy Information Program to a point where the motoring public will have access to, and confidence in, information of importance to them in making new car purchase decisions.

B. Design Parameter Sensitivity

1. Introduction

The EPA currently calculates a general "model type" label for vehicle fuel economy. This general label value is usually based upon the average of several tested vehicle designs. Thus it occurs that vehicles having a variety of different design characteristics (e.g. weight, axle ratio, road load horsepower) all receive the same label fuel economy value. For those designs which are tested, the label value may not (and frequently does not) correspond to the test MPG values; for those designs which are not tested, design differences from the tested cars are not accounted for. To provide a method for resolving such potential discrepancies, vehicle design parameter sensitivities have been determined which allow adjustment of fuel economy test data for specific vehicle design parameter variations.

To quantify the relations between vehicle fuel economy and specific vehicle design parameters, the fuel economy impacts of differences in weight, road load horsepower, and axle ratio have been determined. (Although more technically appropriate than axle ratio, the parameter N/V is not addressed in this section because it is not as readily available for all vehicles for fuel economy adjustment. Sensitivity regression equations for N/V are given in Appendix F.)

2. Data Sources

Sources for the data for the vehicle design parameter sensitivity analysis are as follows:

a. Weight and axle ratio sensitivity: Model Year 1975-1980 General Label files;

b. Road load sensitivity: Based on unpublished EPA data, and on Ref. 9.

3. Analysis

Design adjustment factors were obtained for weight (W), road load horsepower (RLHP), and axle ratio (AR). The methodology used to obtain the adjustment factors is described below.

a. Within discrete basic engines, test vehicles identical in all configuration specifications except the design parameter in question were paired and their fuel economy and design parameter values used to determine sensitivity coefficients for city and highway fuel economy. Approximately 2000 vehicles were involved in the analysis. A sample calculation follows:

W_1 = 3000 lb.

FE_1 = 19.6 MPG

W_2 = 3500 lb.

FE_2 = 19.3 MPG

Sensitivity, S, is calculated for city FE using the following equation:

$$S = \frac{\Delta FE/\bar{FE}}{\Delta W/\bar{W}}$$

$$= \frac{(FE_1-FE_2)/\frac{(FE_1 + FE_2)}{2}}{(W_1-W_2)/\frac{(W_1 + W_2)}{2}}$$

Using the values given earlier:

$$S = \frac{(19.6-19.3)/\frac{(19.6 + 19.3)}{2}}{(3000-3500)/\frac{(3000 + 3500)}{2}}$$

$$S = -.1002$$

Based on this coefficient, a 10% weight increase would result in a 1.002% fuel economy decrease.

b. The W, AR, and RLHP sensitivity factors were then regressed against W, AR, and RLHP, respectively for city and highway values, resulting in two regression equations for each of the three design parameters. See Figure 1.

4. Results

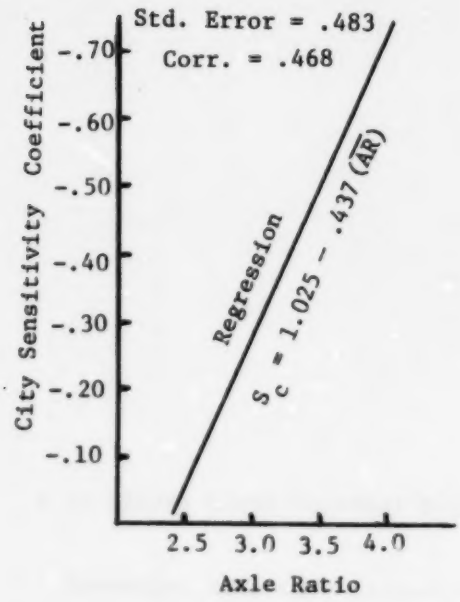
a. Typical sensitivity factors determined from the above analyses are as follows:

	City	Highway
Sensitivity to ΔWeight (at 3000 lb.)	-0.37	-0.31
Sensitivity to ΔRLHP (at 10 HP)	-0.17	-0.35
Sensitivity to ΔAxle Ratio		
without overdrive (at AR = 2.0)	-0.30	-0.55
with overdrive (at AR = 2.31)	-0.30	-0.55

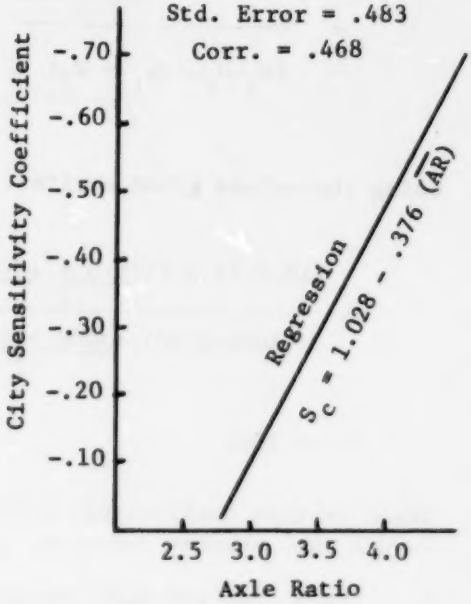
Figure 1

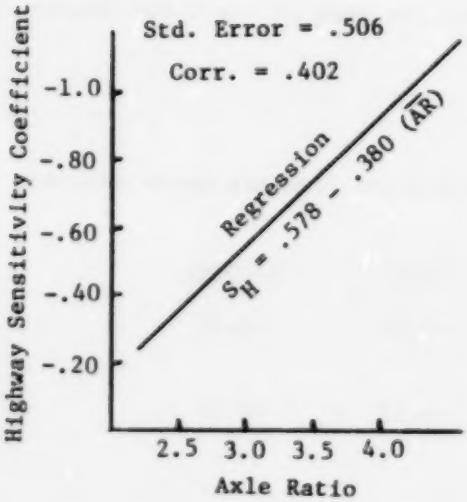
Design Sensitivity Parameter
Regression Equations

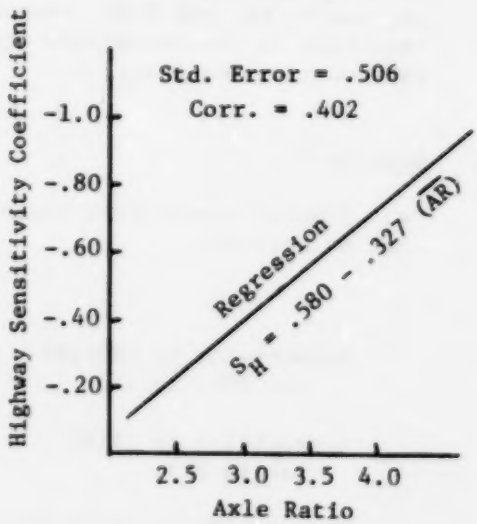
MPG Sensitivity to Axle Ratio
(without overdrive)



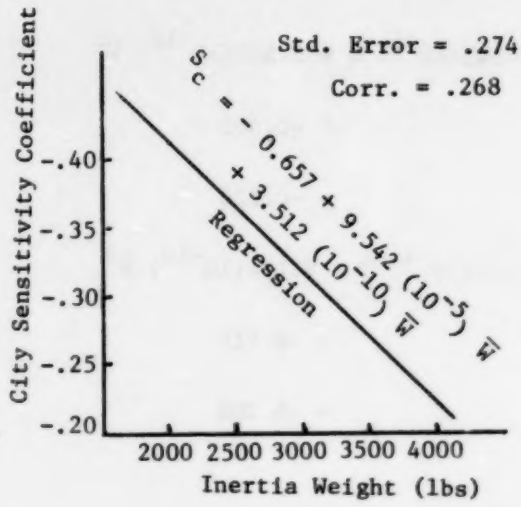
MPG Sensitivity to Axle Ratio
(with overdrive)



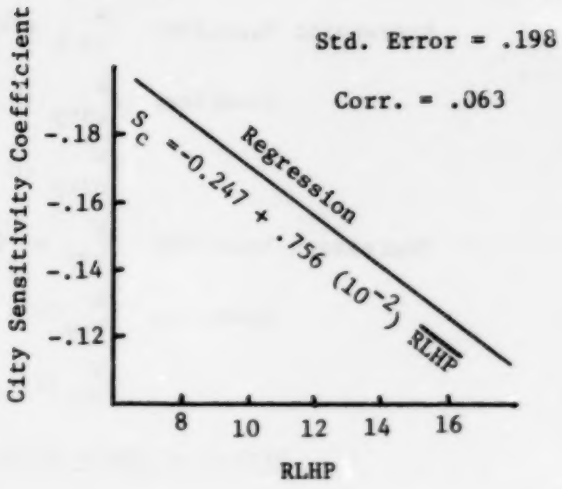


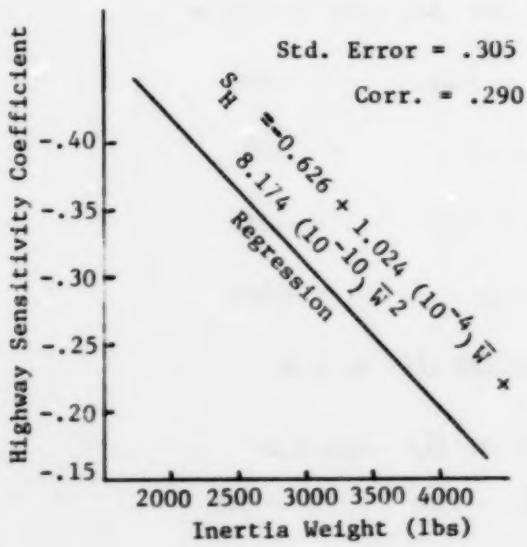


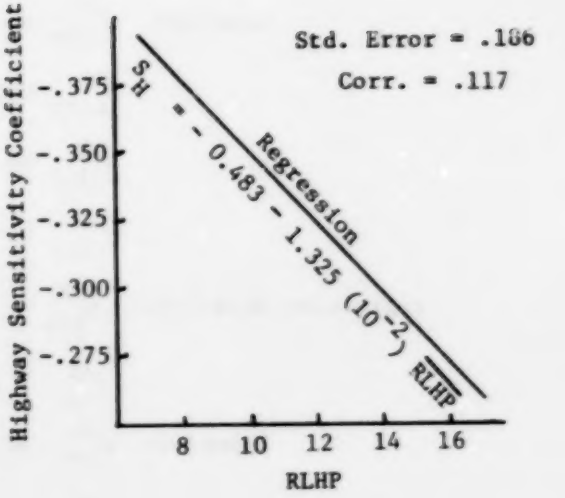
MPG Sensitivity to Vehicle Weight



MPG Sensitivity to Road Load Horsepower







Note - When using the parameter regression equations given below, the sensitivity coefficients obtained are only valid for values of the design parameters which yield negative coefficients. A calculated sensitivity coefficient greater than zero should be set equal to zero.

b. Effect of ΔWeight

Regression Equation: $S^{W}_{city} = -0.657 + 9.542(10^{-5})\ \bar{W} + 3.512(10^{-10})\ \bar{W}^2$

Examples: S^{W}_{city} ($\bar{W}$ = 2000) = -0.465

S^{W}_{city} ($\bar{W}$ = 4000) = -0.270

Regression Equation: $S^{W}_{hwy} = -0.626 + 1.024(10^{-4})\ \bar{W} + 8.174(10^{-10})\ \bar{W}^2$

Examples: S^{W}_{hwy}($\bar{W}$ = 2000) = = -0.418

S^{W}_{hwy}($\bar{W}$ = 4000) = -0.203

c. Effect of ΔAxle Ratio

Regression Equations: $S^{AR}_{city} = 1.025 - 0.437\ (\bar{AR})$ No Overdrive

$S^{AR}_{city} = 1.028 - 0.376\ (\bar{AR})$ with Overdrive

Examples: S^{AR}_{city} No O.D. ($\bar{AR}$ = 3.0) = -.286

S^{AR}_{city} O.D. ($\bar{AR}$ = 3.0) = -.100

S^{AR}_{city} No O.D. ($\bar{AR}$ = 4.0) = -.723

S^{AR}_{city} O.D. ($\bar{AR}$ = 4.0) = -.476

Regression Equations: $S^{AR}_{hwy} = 0.578 - 0.380\ (\bar{AR})$ No O.D.

$S^{AR}_{hwy} = 0.580 - 0.327\ (\bar{AR})$ with O.D.

Examples: S^{AR}_{hwy} No O.D. ($\bar{AR}$ = 3.0) = -.562

S^{AR}_{hwy} O.D. ($\bar{AR}$ = 3.0) = -.401

S^{AR}_{hwy} No O.D. ($\bar{AR}$ = 4.0) = -.942

S^{AR}_{hwy} O.D. ($\bar{AR}$ = 4.0) = -.728

d. Effect of ΔRLHP

Regression Equation: $S^{RLHP}_{city} = -0.247 + 0.756(10^{-2})\ \overline{RLHP}$

Examples: $S^{RLHP}_{city}\ (\overline{RLHP} = 8) = -0.186$

$S^{RLHP}_{city}\ (\overline{RLHP} = 16) = -0.126$

Regression Equation: $S^{RLHP}_{hwy} = -0.483 + 1.325(10^{-2})\ \overline{RLHP}$

Examples: $S^{RLHP}_{hwy}\ (\overline{RLHP} = 8) = -0.377$

$S^{RLHP}_{hwy}\ (\overline{RLHP} = 16) = -0.271$

The mere existence of parameter sensitivity algorithms does not in itself assure that their use would have any practical benefit. Use of such algorithms is worth considering only if their interaction with design parameter differences encountered in actual practice is "strong enough" to change fuel economy label values by one whole number or more. A review of fifteen sales-significant 1980 engine families showed that axle ratio difference of 0.5, weight differences of three ETW classes (375 lb), and road load horsepower differences of 1.5 Hp are quite common within the same configuration. Using these typical design differences the algorithms show that:

- an axle ratio difference of 0.5 in the neighborhood of $\overline{AR}$=3.5 will cause MPG differences exceeding 1 MPG for all label values $\geq$ 24 city and/or $\geq$ 12 highway;
- a weight difference of 375 lbs. in the neighborhood of 3000 lbs. will cause MPG differences exceeding 1 MPG for all label values $\geq$ 22 city and/or $\geq$ 26 highway;
- a road load horsepower difference of 1.5 Hp in the neighborhood of 8 Hp will cause MPG differences exceeding 1 MPG for all label values $\geq$ 29 city and/or $\geq$ 14 highway.

5. Conclusion

Certain vehicle designs vary sufficiently from those of the nearest tested vehicle designs to cause errors in fuel economy label values of 1 MPG or greater; application of weight, axle, and road load sensitivity algorithms should be used to reduce vehicle mislabeling due to unaccounted-for design variances for untested vehicle subconfigurations. Section D illustrates the improvements in labeling that would result from the use of design sensitivity factors. In situations where a manufacturer can show that the above universal algorithms are not reflective of his own vehicles' behavior, EPA could consider the use of alternate, manufacturer-specific sensitivity algorithms.

C. Road MPG Factors

1. Introduction

A number of "real world" influences which can cause differences between the EPA MPG figures and in-use experience have been identified and quantified by the 404 Report. Because of uncertainties as to how these influences act in combination, however, it is not practicable at this time to devise EPA-to-road adjustment factors on an analytical basis. Fortunately, in-use data exists in sufficient quantity to permit empirical estimates of road adjustment factors.

2. Data Sources

Although numerous bodies of in-use MPG data are available from fleet operators' records, it appears, as pointed out in the 404 Report, that such non-consumer data may not be fully appropriate for developing road adjustment factors for fuel economy information intended primarily for consumer use. Hence, this report's analysis concentrates on three groups of available data representing consumer driving.

a. General Motors 1975 Customer Survey: This data base includes in-use MPG for some 1500 privately-owned new 1975 GM models, based on postcard logs of odometer mileage and fuel quantity for three successive fuel purchases, with (at least) the first and last purchases being fill-ups. This was a nationwide random sample, and covered 47 nameplates from all five GM divisions, operated under both summer and winter driving conditions.

b. Ford 1978 and 1979 Lease Car Survey: This is also a new-car postcard type survey, covering some 20,000 Ford Motor Co. vehicles split about equally between the two model years covered. Winter and summer driving conditions are both included. Strictly speaking, these cars were not privately owned, being leased to Ford Motor Co. employees; they were, however, used in personal/commuter transportation rather than fleet service. A valuable parameter logged in this survey was the estimated fraction of urban driving for each car during its survey interval.

c. J.D. Power Survey: This DOE-sponsored survey was a questionnaire survey which gathered in-use MPG estimates (along with a large amount of other information related to consumer opinions on the usefulness of the label/guide program and the importance of fuel economy in vehicle purchase decisions) from about 10,000 purchasers of new 1978 and 1979 vehicles. The survey was a nationwide random sample, and covered vehicles from most domestic and import manufacturers. As did the Ford survey, this survey acquired data on urban driving fraction. While the J.D. Power data base has the advantage of multiple manufacturer representation, it has two disadvantages which may be of some significance:

(1) The in-use fuel economy economy values are single MPG estimates, rather than figures calculated from odometer readings and fuel qantities. In many cases, the respondents indicated the figures

were not based on record-keeping at all, but were literally only perceptions of their vehicles' in-use MPG performance. It has been observed that owner-perceived in-use MPG generally is overly optimistic (possibly due to measuring MPG only when convenient, as in a long trip), so the influence of this type of data could result in underestimation of the in-use shortfall.

(2) The questionaires used for this survey did not include blanks for specifying the displacement of the engine in the respondent's vehicle; only the number of cylinders. Consequently, the EPA MPG values assigned to many vehicles were the average of all label/guide values for all available engines of a given number of cylinders. While this could introduce dispersion in the data moreso than affecting mean values, it is possible that some directional error (bias) could exist in the resulting shortfall values.

3. Analysis

Early in the course of analyzing these available data for road adjustment factors, it became clear that there is not just one labeling strategy to be addressed. There are a number of plausible interpretations of the data, uses of the various EPA values, and options for presentation of label values, depending upon what information the label figure(s) is/are intended to convey. Accordingly, this study developed unique road adjustment factors for each of six labeling options, defined as follows:

Option 1, "Two-mode Median" - two MPG values are given, representing the median values of expected in-use fuel economy in "urban" driving and in "non-urban" driving, respectively. The values are derived from the EPA City and Highway figures.

Option 2, "Range, 90% Inclusion" - two MPG values derived from EPA City and Highway figures are used, but they do not relate to specific driving modes; instead, they reflect, respectively, a low MPG figure which 95% of drivers exceed, and a high MPG figure which only 5% of drivers exceed. The two figures thus bound an MPG range within which 90% of all driving experience falls.

Option 2a, "Range, 60% Inclusion" - this is a variant of the 90% inclusion range approach. Again, two values based on the EPA City and Highway figures are used, but the inclusion range is 60%; 20% of drivers achieve MPG below the lower figure, and 20% exceed the higher figure.

Option 3, "Two-mode, Ten Percentile Estimate" - this is a conservative version of Option 1's two-specific-mode strategy, except instead of reflecting average respective City and Highway experience, the values presented are such that 90% of urban driving MPG will exceed the lower figure and 90% of non-urban driving will exceed the higher figure; the two figures, then, are "9-out-of-10 guarantees" of MPG performance in each of the two driving modes.

Option 4, "One-mode Median, City Basis" - this is a one-number system based on the EPA City figure only. In effect, it assumes that in-use average MPG for all driving is linearly proportional to the EPA City figure for all vehicles, whether their Highway-to-City MPG relationships are equivalent or widely different.

Option 4a, "One-mode Median, 55/45 Basis" - this one-number system uses the EPA combined City-Highway value as its basis.

The road factors for each of these options were determined separately for each of the three data sources. The sample sizes in these data bases were large enough so that the various percentile cutpoints needed to determine the road factors did not have to be calculated from statistical formulae -- they were read directly from histograms of ratios of road MPG to EPA MPG. For options 1 and 3, the ratios histographed were Road Urban/EPA City and Road Non-urban/EPA Highway. "Urban" and "Non-urban" vehicle subsets of the Ford and J.D. Power data were defined to include those vehicles with urban fractions of 90% or greater, and 20% or less, respectively. For illustration, the characteristics of these two subsets from the Ford data are shown below. This illustration shows that the shortfall from either of the EPA values depends strongly on the type of driving involved.

TABLE I
Characteristics of Urban and Non-Urban Driven Cars
-- 1978-79 Ford In-Use Data --

	Urban Driven Cars	Non-Urban Driven Cars
Definition	$\geq$ 90% Urban	$\leq$ 20% Urban
Number of Cars	4376	4868
Average Miles/Day	27.0	91.5
Average Odometer	3766	6562
Average EPA City MPG	16.28	16.21
Average EPA Hwy. MPG	22.83	22.94
Average Road MPG (actual)	14.02	17.62
Average Road MPG (4000 mi)	14.14	17.55
Average Weight, lb	3864	3908
Average CID	281	287

Reference 10 gives specific values for alternate definitions of urban and non-urban cars, and indicates no significant sensitivity between the subset definitions and their shortfall characteristics.

For the GM data, which did not include urban fraction, the two subsets had to be defined using average miles per day (AMPD) as a surrogate determinant of urban fraction. Those low AMPD records which yielded an aggregate average AMPD of 27.0 were defined as the urban subset, and those high-AMPD samples which averaged 91.5 were defined as the non-urban subset.

For options 2 and 2a, the ratios histographed were Road/EPA city and Road/EPA Highway, the Road values in both cases being those of all of the data, not just modal subsets.

For option 4, the analysis was based on the Road(all)/EPA City ratio and for option 4a the Road(all)/EPA combined ratio.

The table below gives the road adjustment factors for the three separate data sources. For this analysis, which is only an illustration of the use of road adjustment factors, the average values (in the last column) were used.

Table II
Summary Table of Adjustment Factors

Option		J.D.Power 1978 - 79*	Ford 1978 - 79	GM 1975	Average All 3
1.	Two-mode Median, City	.88	.86	.96	.90
	Highway	.82	.75	.79	.79
2.	Range, 90% inclusion, City	.69	.70	.73	.71
	Highway	1.03	.91	.91	.95
2a.	Range, 60% inclusion, City	.85	.82	.87	.84
	Highway	.84	.82	.83	.83
3.	Two-mode, 10%-tile estimate, City	.65	.69	.77	.70
	Highway	.65	.62	.66	.64
4.	One-mode Median (city basis)	1.00	.94	1.00	.98
4a.	One-mode Median (55/45 basis)	.88	.81	.89	.86

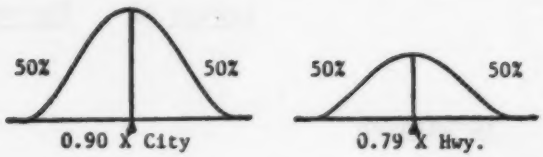
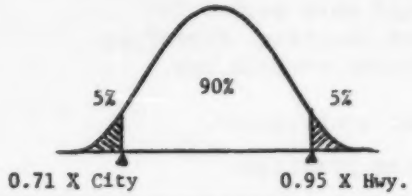
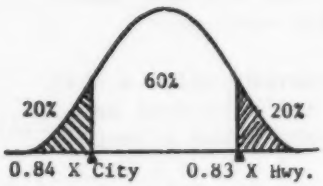
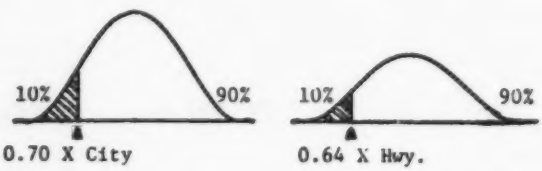
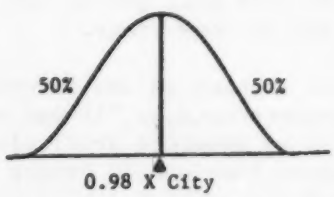
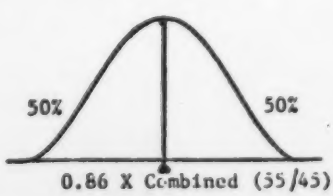
* The factors from the J.D. Power survey were derived from consumer perceived fuel economy, not actual.

Figure 2 illustrates the distribution cuts and average road factors from table II.

Each of the six labeling strategies has its own combination of advantages and disadvantages. These are given in the pro/con analysis following figure 2.

Figure 2

Options for Use of
Road Adjustment Factors

OPTION 1 Two-mode Median	
OPTION 2 Range 90% Inclusive	
OPTION 2a Range 60% Inclusive	
OPTION 3 Two-mode 10 - Percentile Estimate	
OPTION 4 One-mode Median (City Basis)	
OPTION 4a One-mode Median (55/45 Basis)	

Pro/con analysis of labeling options

Option 1: Two-Mode Median

Advantages

-Bimodal driving patterns perceived by the public

-Two numbers more useful for comparison shopping, depending upon intended vehicle use.

-Consistent with current advertising practices[8,11]

-Half of the population will get better than the MPG number presented for each mode

-Consumer studies indicate that EPA values are perceived as discrete rather than a range[6,8,11]

-Highway shortfall will be reduced substantially

Disadvantages

-Half the population will get less than the MPG number presented for each mode

-The adjusted highway number in some rare instances may be equal to, or even less than the city number

Option 2: Range, 90% Inclusive

Advantage

-90% of all drivers will get within specified fuel economy range.

-Range of fuel economy values favored by some consumers because "it was an indicator not an absolute prediction" of fuel economy they should expect to receive[4,8]

Disadvantages

-Consumers seem to perceive EPA values as discrete rather than a range[6,8,11]

-Range may not be as convenient for comparison shopping for city or highway specific drivers

-90% range could be perceived as overinclusive, opening EPA to more criticism(i.e., "why don't they use one label saying all vehicles will get between one and 100 MPG").

Option 2a: Range, 60% Inclusive

Advantages

-60% of the population will achieve fuel economy within the range

-The 60% range is not overly inclusive

-Range is a good indication of fuel economy rather than an "absolute indication"[4,8]

Disadvantages

-Consumers seem to perceive EPA values as discrete rather than a range[6,8,11]

-Range may not be as convenient for comparison shopping for city or highway specific drivers

-40% of the population will not achieve within the specified range

Option 3: Two Mode 10%-tile Estimate

Advantages

-Bimodal driving patterns perceived by the public[11]

-Two numbers useful for comparison shopping[11]

-Consistent with current advertising practices[8,11]

-90% of population will achieve the MPG number or better for both city and highway modes

Disadvantages

-Guaranteeing 90% of the population will achieve better than the MPG numbers may be perceived as intentional underestimation of MPG numbers to minimize complaint letters rather than convey meaningful information on achievable fuel economy.

-The two MPG values resulting from this scheme are numerically very close; those who insist on perceiving the numbers as a range will interpret it as a virtual guarantee of MPG to be achieved.

-Since MPG distributions cannot be discerned from one tail, these figures cannot be used for any meaningful fuel demand forecasting or annual fuel cost computation.

Option 4a: One Mode Median (55/45 Basis)

Advantages

-Compatible with current label format used

-Half of population will get better than MPG number presented

-Compatible with CAFE compliance and gas guzzler programs: if the fudge factor is known, the raw EPA 55/45 number can be determined for each car.

-One number may be less confusing to consumers

Disadvantages

-The 55/45 split is representative of the population average, but only represents a small fraction of individuals' driving habits[10]

-Consumers indicate a preference for a two number system

-One number system not consistent with current advertising practices

-Least useful for comparison shopping (see chart below)

-Half the population will get worse than MPG number presented

Three Cars, Same 55/45 MPG

Car	City	H/C Ratio	Hwy	55/45
A_2	23	1.3	30	26
B_2	22	1.5	33	26
C_2	21	1.7	36	26

Note differences in City and Highway MPG ranking for vehicles with varying H/C ratios when a combined one number system is used to represent estimated MPG. City drivers are led to believe the cars have equivalent MPG, when car A_2 would be the better choice; Highway drivers are also led to believe equivalence, whereas car C_2 should be better for their driving pattern.

4. Conclusions

Except for the two-mode 10 percentile option, all of the two-number labeling schemes are special cases in a continuum of interrelated two-mode descriptors and range descriptors; they are not independent. The Two-mode Median option has range inclusion properties, and the range options have two-mode properties, as shown below:

			% of City Driving			% of Highway Driving	
Option	Inclusion Range	City Factor	Below	Above	Highway Factor	Below	Above
2	90%	0.71	11%	89%	0.95	91%	9%
2a	60%	0.84	35%	65%	0.83	63%	37%
(not shown)	50%	0.87	43%	57%	0.81	56%	44%
1	40%	0.90	50%	50%	0.79	50%	50%

Of the one-number systems evaluated, the one based on the EPA combined 55/45 figure (Option 4a) is preferable in that it provides a link to the EPA MPG rating used in the CAFE compliance and Gas Guzzler programs; however, it may be inferior to the City-MPG based system (Option 4) in that it could mislead both city-driving car buyers and highway-driving car buyers.

Either of the one-number systems would be somewhat "cleaner" than multi-number systems in the cosmetic sense, offering less clutter in the label and Guide; however, reducing clutter may not provide all the information desired by consumers.

For all road labeling options, the road adjustment factors are developed from data sources that surveyed mainly gasoline-fueled, rear-wheel driven passenger cars. The resulting factors may or may not accurately reflect road shortfalls for vehicles which are Diesel powered and/or front-wheel driven and/or trucks.

Three-number or four-number labeling schemes could be developed from the six options evaluated, e.g., adding option 4a's combined city-highway based value to the two figures from Option 1, combining Options 1 and 3 to yield 10 percentile and 50 percentile numbers for city and highway driving, etc.

The ease of calculation of an annual fuel cost (AFC) figure varies among the options estimated:

- for both of the one-number systems, AFC calculation is completely straightforward:

- for the Two-mode Median option, AFC can be calculated from a 55/45 weighted average of the two figures, since the figures do represent modal driving;

- for both of the Range options, AFC could be calculated from a 55/45 weighted average of the two figures, although the two figures are not directly associated with driving modes;

- for the Two-mode Ten Percentile option, there is no way to calculate AFC, because the location of the means of the two modal distributions cannot be discerned from only the 10 percentile cutpoints.

Policy and regulatory considerations beyond the scope of this Technical Report must figure in the final selection of options to be proposed, and the system to be adopted, for the fuel economy labeling regulations.

It is important to note that additional analysis of the data sources used herein, and other data sources which may become available to EPA, must and will be conducted; the rulemaking process in fact requires continued analysis through the duration of the public input/comment period. Some important issues which will be receiving analytic attention between publication of this report and the shaping of the final rule are:

- the form of the road adjustment. Instead of the use of constant multiplicative factors, it may be more accurate and appropriate to specify sets of constant MPG offsets (e.g. Road MPG = EPA MPG minus two MPG) or constant GPM offsets (e.g. road GPM = EPA GPM plus 0.007 GPM), or MPG-dependent versions of these.

- the applicability of unique road adjustment schemes to specific classes of vehicles. It may well be that separate road adjustment systems are warranted for certain generic types of vehicles, such as trucks, Diesel-powered vehicles, front-wheel drive vehicles, certain combinations of these, and/or other vehicle types. At this point there is simply not enough data to develop unique road adjustment schemes down to the individual model type level, but there is already some preliminary evidence that some broad classes of vehicles may be deserving of unique adjustments.

- the data sources, particularly those of older model years, must be further evaluated with respect to their representativeness and statistical significance. To be useful/representative, in-use data bases should include, as much as practicable, measured fuel economy, seasonal representation (summer and winter), reasonable geographic coverage, some identification of type of driving involved, e.g. % urban, reasonable coverage of the product line, and enough individual vehicle data (transmission type, engine CID, etc.) to facilitate accurate assignment of EPA MPG values to the vehicle records.

D. Adjusted Labeling

1. Introduction

Label values are currently calculated for new cars by figuring a sales-weighted harmonic average of all the tested vehicles in a base level (unique combination of basic engine, inertia weight and transmission class) which are then combined for each model type. Since in a base level many of the configurations receive at least one fuel economy test, it is possible in some cases to apply a label value that represents the test results for a given vehicle more specifically than the average base level value.

Vehicles are tested on a subconfiguration level, which may differ by test weight or road load horsepower within a configuration, and configurations can vary by axle ratio or engine code within a base level. If all the subconfigurations were tested, it would be easy to recommend the use of those specific test results for the labels on those subconfigurations. Because less than 20% of the technically unique subconfigurations are tested, some alternative must be sought.

An untested vehicle which differs only slightly from a tested vehicle in the design parameters of axle ratio, road load horsepower, or test weight can be labeled with a value derived from the label on the tested vehicle. A set of fuel economy sensitivity algorithms was created to account for differences in these design parameters (see section B). With these algorithms, specific labels can be prepared for 60% of the new car fleet.

The remaining vehicles differ by at least engine code or transmission configuration from a tested vehicle. It might be possible, for some of these, to develop a transmission adjustment or to ignore engine code differences within an engine family.

2. Analysis

The 1980 light-duty certification fuel economy data base was analyzed, concentrating on the 60% which is either directly tested or can be simply adjusted for slight differences in design parameters. A road factor was also applied to both the City and Highway MPG's, not to obviate the issues brought up in section C of this report, but to show, for illustration purposes, a typical road adjustment.

Data were prepared in two steps. The first step was to create a file containing one entry for each subconfiguration in the certification data base for 1980. This involved reading 9467 vehicle records ("card 5's"), collapsing them to 5541 technically unique subconfigurations, and consulting the results of 2125 manufacturer's tests and 997 EPA tests. The collapsing was done for records which were identical in all technical specifications, differing only in car line. Where several tests were applicable to a given vehicle the results were harmonically averaged, sample weighted.

The second step was to develop a uniform basis for comparing several different labeling schemes. These 3 schemes are:

a. Base level labeling - similar to the current system, this system uses sales-weighted average fuel economy (FE) values for all the members of a base level.

b. Tested subconfiguration specific labeling- if a subconfiguration was tested, the test value is used; if not, the base level value is used.

c. Sensitivity adjusted labeling - if a subconfiguration was tested, the test value is used; if not, the FE's of the tested vehicles with the same engine code, in the same base level, are adjusted for the differences in design parameters, and the result is harmonically averaged for this vehicle.

The sensitivity adjustments were made using a FORTRAN subroutine (see appendix A) based on the following algorithm:

The sensitivity S of FE to perturbations in design parameter X,

$$S = \frac{\partial FE}{\partial X}$$

has been separately determined for test weight, axle ratio, and road load horsepower. For calculation purposes,

$$S = \frac{\Delta FE/\overline{FE}}{\Delta X/\bar{X}}$$

$$\text{or} \quad FE_2 - FE_1 = FE_2\left(\frac{2S\Delta X}{2\bar{X} + S\Delta X}\right)$$

Where FE_1 is the unknown value and FE_2 is the tested value.

If there is more than one design parameter adjustment, the ΔFE's are added arithmetically. As discussed in the 404 Report, aritmetic addition of ΔFE's provides a better estimate of combine MPG effects then does a product of MPG factors.

The three versions of City FE were multiplied by a road factor of 0.86, and the Highway FE by 0.75, to form six more FE values, for a total of 12 for each record. Of the 5541 subconfigurations read, 1227 were rejected because they were untested and projected to have zero sales, and 1781 were rejected because they belonged to untested configurations. 938 base levels were realized for 1980. This analysis addresses only tested or adjustable subconfigurations and leaves open the question of how to label untested engine codes.

These procedures were first run on a small data base of 15 high-selling engine families (524 subconfigurations), and the results agreed with manual analysis of the 15-family sample.

3. Results

The twelve MPG values in each subconfiguration record are actually six pairs of City and Highway values, as described above:

EB = base level label
ET = tested subconfiguration specific label
EA = sensitivity adjusted value
RB = road adjusted base level
RT = road adjusted tested subconfiguration specific label
RA = road adjusted sensitivity adjusted value

The following six histograms show the distributions of differences between options EB, RB, RT, and RA, using RA as the reference. Because road adjustment causes a much larger shift than specific test labeling or sensitivity adjustment, ET and EA were not charted. For Figure 3, differences were tabulated to the nearest integer, and subconfigurations belonging to untested configurations were omitted. For tabulations of actual values, see Appendix B.

Histograms of similar differences using EB and RB as references are contained in Appendix C, and illustrate how the alternate schemes change label values relative to these references.

4. Conclusions

The charts in Figure 3 were prepared to contrast four alternative labeling schemes: base level labeling, road-adjusted base level labeling, road-adjusted specific-tested subconfiguration labeling, and road-adjusted specific-tested sensitivity-adjusted subconfiguration labeling. Assuming the last alternative gives the most accurate label, the charts show several things:

a. Road adjustment shifts the data by about 2.7 MPG city and 6.5 MPG highway, without affecting its spread very much. Since the FE vector is multiplied by a road factor, and the results are subtracted, the resulting spread is due partly to the analysis and not solely to the data. For this reason the other comparisons are made against road adjusted labels.

b. Without road adjustment the other improvements have a negligible effect on reducing shortfall.

c. Road adjustment raises the fraction labeled the same from about zero to about 75%. Specific test labeling increases this fraction by 10-15%, and sensitivity adjusting picks up another 10-15%. No conclusions can be reached about the label accuracy of subconfigurations whose engine codes were not tested.

d. Without both specific testing and sensitivity adjusting there are vehicles mislabeled by as much as 4 MPG.

9. Data show that drivers, on a "snapshot" basis, drive in one of two general modes: either predominantly low average speed stop-and-go travel or predominantly higher average speed quasi-cruise travel; moreover, surprisingly few individuals average a 55/45 split between the two modes on an elapsed time basis. See Appendix E.

10. When asked directly what kind of fuel economy information system (number of numbers) they prefer, 88% of focus group participants indicate they favor a multi-number system. However, note that this sample size was only about 250, and it is not certain how leading the questions put to the focus groups were.

11. In spite of Conclusions 9 and 10, the close agreement between the EPA City figure (which simulates idealized stop-and-go urban driving only) and average in-use MPG (which comes from the pooled results of all types and conditions of driving) is a numerical coincidence whose espousal on purely pragmatic grounds has been once, and could be again, an irresistible temptation.

12. The most beneficial single change that can be made to the labeling system is the incorporation of road adjustment factors, which (for the Two-mode Median option) raises the fraction of vehicles labeled "correctly" from less than 1% to about 75%.

13. Once road factors have been applied, specific labeling of tested subconfigurations increases the percent labeled accurately by an additional 10-15%; the incremental benefit of going further and using design parameter sensitivity adjustments for untested subconfigurations is another 10-15%.

14. The use of specific labeling without application of road factors is of no significant benefit to label accuracy.

15. A significant fraction (40% in 1980) of vehicle subconfigurations have labels of undeterminable accuracy, since their engine codes are untested. Keeping Conclusion 8 in mind, there is the possibility of improving test coverage over the engine code spectrum without significantly increasing overall test burden, by using sensitivity adjustment to reduce test coverage over the design paramenter spectrum.

REFERENCES

(1) U.S. Environmental Protection Agency, "Passenger Car Fuel Economy: EPA and Road," Report EPA 460/3-80-010, September 1980. ("404 Report").

(2) House Committee on Government Operations, "Automobile Fuel Economy: EPA's Performance," Report 96-948, May 13, 1980 ("Moffett Report").

(3) Scardino, Birch, and Vitale, "Impact of the FEA/EPA Fuel Economy Information Program", June, 1976 ("ABT Study").

(4) Porter and Novelli, "Report on Focus Groups, Gas Mileage Information Program," February 1978 ("EPA Focus Group").

(5) M. Hunt, et al, "Preliminary Report on Study and Evaluation of DOE Vehicle Energy Efficiency Programs", April 1980 ("J.D. Power Report").

(6) EPA Analysis of J.D. Power data systematized by Energy and Environmental Analysis, Inc. (unpublished), in addition to the Power report in Ref. 5.

(7) The New York Times, "Auto Industry Outlook--A National Study of Consumer and Dealer Views," September 1980.

(8) K. Hellman, "Review of the Available Information on the Subject of how many Different Fuel Economy Numbers to Present", Memo to C. Gray, ECTD, August 26, 1980.

(9) Data from S. Martin and K. Springer, "Influence on Fuel Economy and Exhaust Emissions of Inertia, Road Load, Driving Cycles, and N/V Ratio for Three Gasoline Automobiles" Southwest Research Institute Final Report under Task No. 9, EPA Contract No. 68-03-2196, June 1977.

(10) K. Hellman, "Extremes Analysis of Ford In-Use Data Base", Memo to R. Maxwell, CD, September 3, 1980.

(11) K. Tuckey, "One-Number Versus Two-Number Issue Presentation," Draft Issue Paper, August 15, 1980.

APPENDICES

APPENDIX A

FORTRAN Subroutine for Sensitivity Adjustment

```
      SUBROUTINE SF(CARA,CARB,OD)
C     TAKES UNTESTED CAR A AND DEVELOPS NEW FE VALUES FROM TESTED CAR B
C     CARA AND CARB ARE 5-VECTORS.  HERE ARE THEIR INDICES:
C     1 TEST WEIGHT  2 AXLE RATIO  3 ROADLOAD HP  4 CITY FE  5 HWY FE
C     FE'S ENTER AND LEAVE CARA INVERTED(GPM) AND CARB UPRIGHT(MPG).
C     THE FE'S IN CARA ARE BEING HARMONICALLY ACCUMULATED IN THE PARENT ROUTINE
C     OD TRUE INDICATES THE PRESENCE OF OVERDRIVE IN THE TRANSMISSION
      REAL CARA(5),CARB(5)
      LOGICAL*1 OD
      RM(A,B)=0.5*(A+B)
      TH(X1,X2,D,F2)=D-(F2*2*S*(X2-X1))/(X1+X2+S*(X2-X1))
C     TH IS THE SOLUTION TO THE SENSITIVITY EQUATION FOR DELTA FE
      DC=0.0
      DH=0.0
      IF(CARA(1).EQ.CARB(1)) GO TO 20
C     TEST WEIGHT FUDGE
      WB=RM(CARA(1),CARB(1))
      S=-0.657+9.542E-5*WB+3.512E-10*WB*WB
      DC=TH(CARA(1),CARB(1),DC,CARB(4))
      S=-0.626+1.024E-4*WB+8.174E-10*WB*WB
      DH=TH(CARA(1),CARB(1),DH,CARB(5))
20    IF(CARA(2).EQ.CARB(2)) GO TO 30
C     AXLE FUDGE
      ARB=RM(CARA(2),CARB(2))
      IF(OD) GO TO 25
      S=1.025-0.437*ARB
      DC=TH(CARA(2),CARB(2),DC,CARB(4))
      S=0.578-0.380*ARB
      DH=TH(CARA(2),CARB(2),DH,CARB(5))
      GO TO 30
25    S=1.028-0.376*ARB
      DC=TH(CARA(2),CARB(2),DC,CARB(4))
      S=0.580-0.327*ARB
      DH=TH(CARA(2),CARB(2),DH,CARB(5))
30    IF (CARA(3).EQ.CARB(3)) GO TO 40
C     ROAD LOAD FUDGE
      RLB=RM(CARA(3),CARB(3))
      S=-0.247+.00756*RLB
      DC=TH(CARA(3),CARB(3),DC,CARB(4))
      S=-0.483+0.01325*RLB
      DH=TH(CARA(3),CARB(3),DH,CARB(5))
40    CARA(4)=CARA(4)+1.0/(CARB(4)+DC)
      CARA(5)=CARA(5)+1.0/(CARB(5)+DH)
      RETURN
      END
```

APPENDIX B

Data for Histograms in Figure 3 and Appendix C

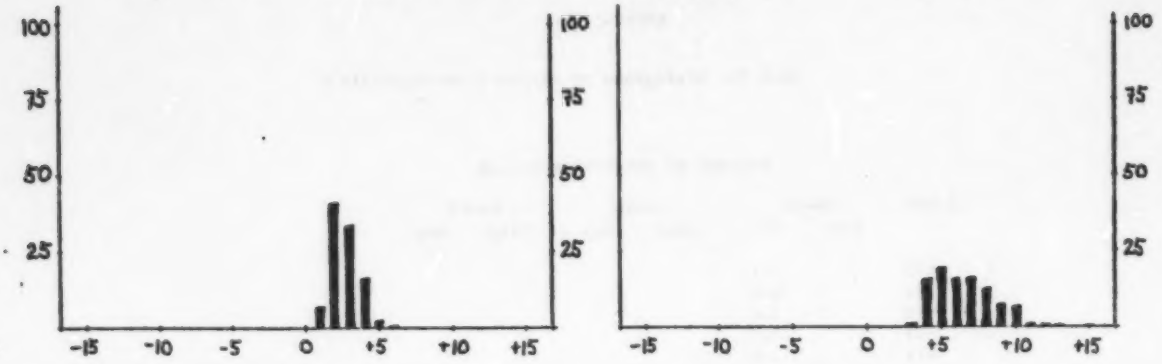
Percent of subconfigurations

ΔMPG	RA-EB		RA-RB		RA-RT	
	City	Hwy	City	Hwy	City	Hwy
-15		0.1				
-14		0.0				
-13		0.6				
-12		1.7				
-11		1.6				
-10		5.0				
-9		8.6				
-8		12.1				
-7		16.0				
-6	0.8	19.3				
-5	3.3	17.8				
-4	16.6	13.0		0.1		
-3	35.0	3.3	0.1	0.5	0.1	0.5
-2	36.0	0.9	1.2	3.4	0.4	0.9
-1	8.2	0.1	11.8	13.5	6.2	7.6
0	0.2		78.5	67.1	89.2	83.7
+1			7.9	11.3	3.9	5.4
+2			0.6	3.7	0.3	1.6
+3				0.5		0.5

ΔMPG	EB-RB		EB-RT		EB-RA	
	City	Hwy	City	Hwy	City	Hwy
0			0.2		0.2	
+1	6.1		7.4	0.1	8.2	0.1
+2	41.5		38.3	0.5	36.0	0.9
+3	34.0	1.8	34.3	3.0	35.0	3.3
+4	16.4	15.7	16.7	12.8	16.6	13.0
+5	1.8	19.4	2.4	19.1	3.3	17.8
+6	0.2	16.9	0.7	18.1	0.8	19.3
+7		16.3		16.5		16.0
+8		13.3		12.8		12.1
+9		7.5		7.9		8.6
+10		6.6		5.8		5.0
+11		1.2		1.4		1.6
+12		0.9		1.4		1.7
+13		0.3		0.4		0.6
+14		0.0		0.0		0.0
+15		0.1		0.1		0.1

ΔMPG	RB-EB		RB-RT		RB-RA	
	City	Hwy	City	Hwy	City	Hwy
-15		0.1				
-14		0.0				
-13		0.3				
-12		0.9				
-11		1.2				
-10		6.6				
-9		7.5				
-8		13.3				
-7		16.3				
-6	0.2	16.9				
-5	1.8	19.4				
-4	16.4	15.7				
-3	34.0	1.8				0.5
-2	41.5		0.2	2.1	0.6	3.7
-1	6.1		3.9	5.8	7.9	11.3
0			89.3	83.3	78.5	67.1
+1			5.6	5.9	11.8	13.5
+2			0.8	2.5	1.2	3.4
+3			0.1	0.3	0.1	0.5
+4				0.1		0.1

Differences between Labeling Options (a)

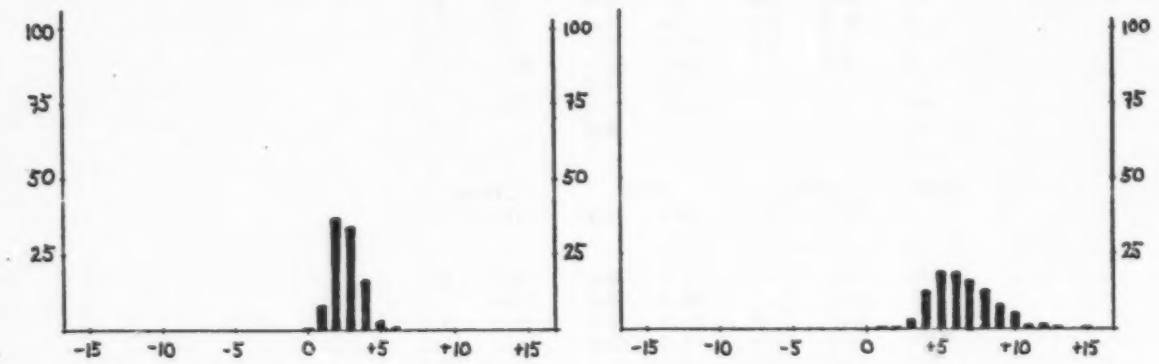


EB-RB City

mean +2.7 0% same

EB-RB Highway

mean +6.5 0% same

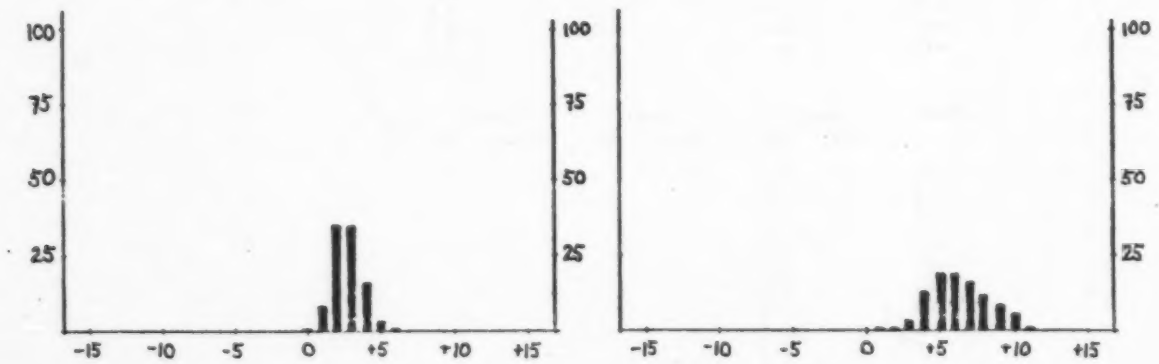


EB-RT City

mean +2.7 0.1% same

EB-RT Highway

mean +6.5 0% same



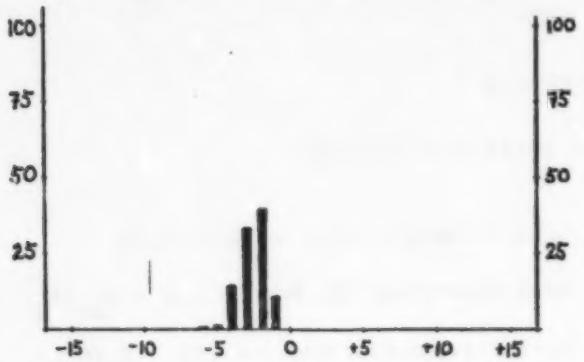
EB-RA City

mean +2.7 0.1% same

EB-RA Highway

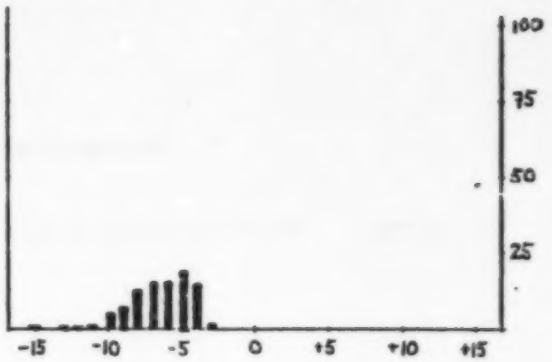
mean +6.5 0% same

Appendix C Differences between Labeling options (b)



RB-EB City

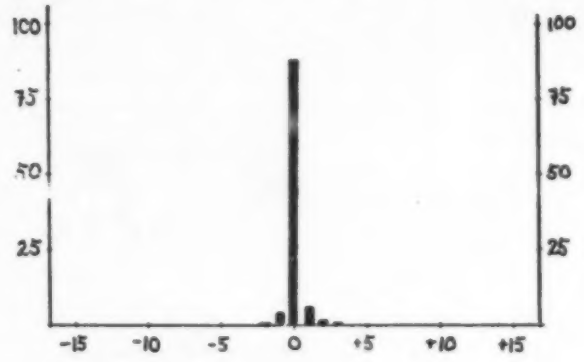
mean -2.7 0% same



RB-EB Highway

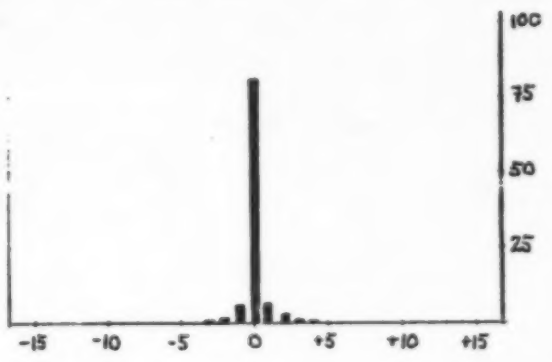
mean -6.5 0% same

Percent of Subconfigurations



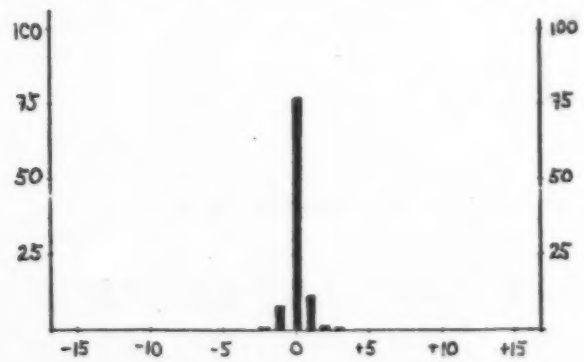
RB-RT City

mean 0.03 89% same



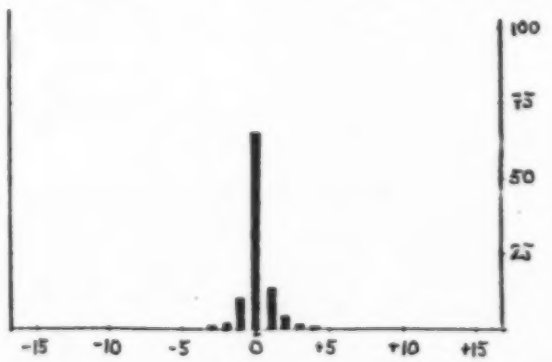
RB-RT Highway

mean 0.02 83% same



RB-RA City

mean 0.05 79% same



RB-RA Highway

mean 0.02 67% same

APPENDIX D

Equivalence of 55/45 Road Factors

Given: Empirical road ratios, Road Urban/EPA City = .90 = R_U/E_C

Road Non-Urban/EPA Hwy. = .79 = R_{NU}/E_H

Road Overall/EPA Comb. = .86 = R_O/E_{Cb}

Now, $$E_{Cb} = \frac{1}{\frac{.55}{E_C} + \frac{.45}{\frac{E_H}{E_C} \times E_C}} = \frac{E_C}{.55 + \frac{.45}{E_H/E_C}}$$

and, $$R'_O = \frac{1}{\frac{.55}{R_U} + \frac{.45}{R_{NU}}} = \frac{1}{\frac{.55}{.90E_C} + \frac{.45}{.79\frac{E_H}{E_C} \times E_C}}$$

$$= \frac{E_C}{\frac{.55}{.90} + \frac{.45}{.79\ E_H/E_C}}$$

so, $$R'_O/E_{Cb} = \frac{.55\ E_H/E_C + .45}{\frac{.55}{.90} E_H/E_C + \frac{.45}{.79}}$$

$$= \frac{.55\ E_H/E_C + .45}{.611\ E_H/E_C + .570}$$

Hence, the ratio of a constructed R'_O to E_{Cb} depends on E_H/E_C:

E_H/E_C =	1.0	1.2	1.4	1.6	1.8	2.0
R'_O/E_{Cb}:	.847	.852	.856	.859	.862	.865

Therefore, $R'_O/E_{Cb} \cong R_O/E_{Cb}$; in words, road combined 55/45 MPG values constructed from Two-mode Median Road Urban and Road Non-Urban figures are essentially equal to road combined MPG values constructed directly by applying the One-mode Median (55/45) road factor to the EPA combined figure.

APPENDIX E

Bimodal Nature of Vehicle Travel

Traffic surveys have shown that vehicle travel is not a smooth continuum of speed. When plotted against average vehicle speed, miles traveled are distributed in two partially overlapping humps. Figure X shows this behavior for a nationally-representative VMT mix (60/40) of travel on "Non-highway" and "Highway" roads. Figure Y illustrates similar patterns for travel in metropolitan areas. Even in such urban driving, the existence of some high-average speed travel (on urban freeways?) is obvious. The data in figures X and Y are essentially instantaneous, or "snapshot" distributions.

Another bimodal aspect of vehicle travel shows up on a more "elapsed time" basis (rather than snapshot), as shown in Figure Z. In this questionnaire survey, 39% of respondents indicated their travel averaged more than 60% urban, and 55% had travel which was less than 50% urban. Only 5% of these 10,000 people approximated a 55/45 urban/non-urban travel split, and the overall <u>average</u> split is 48/52. As a facetious analogy, the U.S. population may indeed <u>average</u> about 50% female/50% male, but very few individuals exhibit the characteristics of the population average.

Figure X

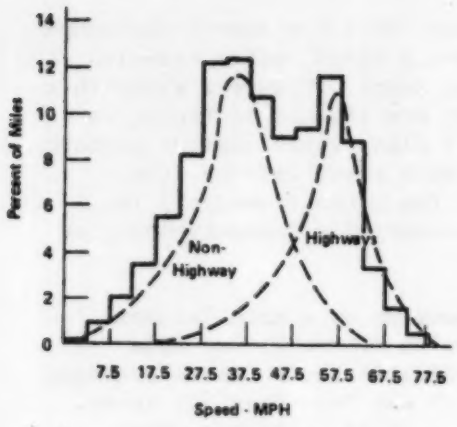


FIGURE 39
PERCENT OF MILES SPENT IN SPEED BANDS

Table 2 - Road Type Statistics

Road Type	Avg. Speed mph	Stops-Per-Mile	% Usage
(Highway)			
Expressway	53.1	.03	19
Expressway-Business Route	46.7	.07	14
Rural Highway	44.7	.10	8
(Non-Highway)			
Suburban Artery	28.6	.77	16
Unpaved Rural	24.5	.55	-
Urban Artery	23.0	1.29	25
Strip Commercialism	22.2	1.41	7
Suburban - No Curb	21.5	.80	-
Suburban - Curb	19.0	1.16	1
Unpaved - Suburban	17.7	.37	-
CBD - No Parking	17.2	2.55	1
Urban	17.2	1.77	4
CBD - Parking	12.4	3.80	3
Shopping Center-Parking Lot	11.5	4.35	-

The predominant influencing factor in determining the distribution of speeds was the fifth category - Road Type. This point is obvious, but what was not so obvious was the overwhelming influence that road type had. Road type so predominantly influenced driving patterns, that other factors such as vehicle type, traffic density, population density, and even individual differences between people, were minor in comparison. (These other factors, however, can potentially influence the road type selected by the driver.) The road type categories can be broken down into two modes of driving as is illustrated by the dashed lines in Figure 39. These two modes of driving can be separated by lumping the road type categories into two groups: Highway and Non-Highway.

Table 2 illustrates the differences between the modes in terms of both average speed and stops-per-mile. Figures 40 and 41 illustrate the speed distributions of the separated modes. Table 3 lists some driving parameters of the two separated modes, as well as driving characteristics of the overall survey. It can be seen, for instance, that the majority of idle time (time spent at speeds less than 2.5 mph) falls into the non-highway mode, as would be expected. Figures 42 and 43 illustrate the distributions of idle times and distance between stops for the two modes.

Source: T. Johnson, et al, "Measurement of Motor Vehicle Operation Pertinent to Fuel Economy", SAE Paper 750003, February 1975.

Figure Y

Figure 1 shows the distributions of distances covered with the indicated microtrip speed for the Scott and GMPG data sets. There are no substantial differences between the two data sets. Both are characterized by a prominent peak at about 40 km/h, presumably corresponding to driving on local streets, and a smaller peak at about 75 km/h, presumably reflecting freeway and highway driving. The valley between the two peaks occurs at about the same speed as the upper limit for the applicability of the linear fuel versus trip time relation, found previously to be about 55 km/h [8]. Urban traffic is thus rather naturally classified into a low-speed regime where fuel consumption increases linearly with trip time per unit distance and a high speed regime where fuel consumption increases with speed due mostly to increasing aerodynamic drag. The large fraction of urban travel falling within this low speed regime, 68% for the Scott data, brings out the potential fuel savings that might be achieved through improvements in urban traffic flow.

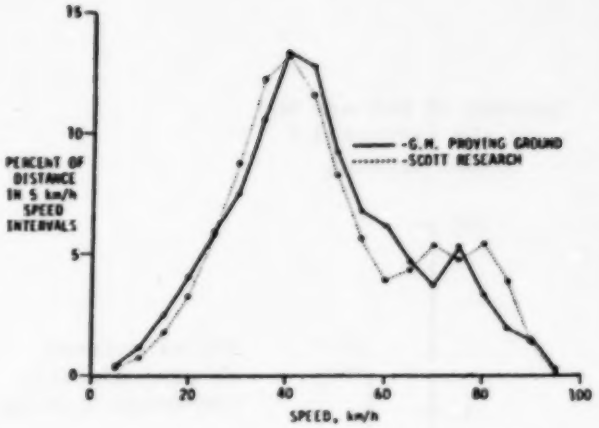


Fig. 1 - Percent of distance driven at indicated microtrip average speed for the two data sets for all cities studied

Microtrip speed distributions are shown in Figure 2 for New York and Los Angeles, the cities with the lowest and highest average speeds, respectively. Both distributions have a qualitatively similar bimodal character, but the two peaks in New York are shifted towards lower speeds compared with Los Angeles. This suggests that the lower average speeds in New York are not due to a different mix of highway and local driving but rather to slower speeds in each of these two categories individually.

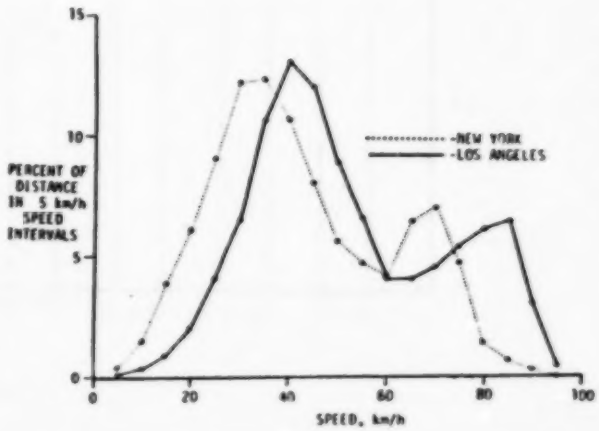
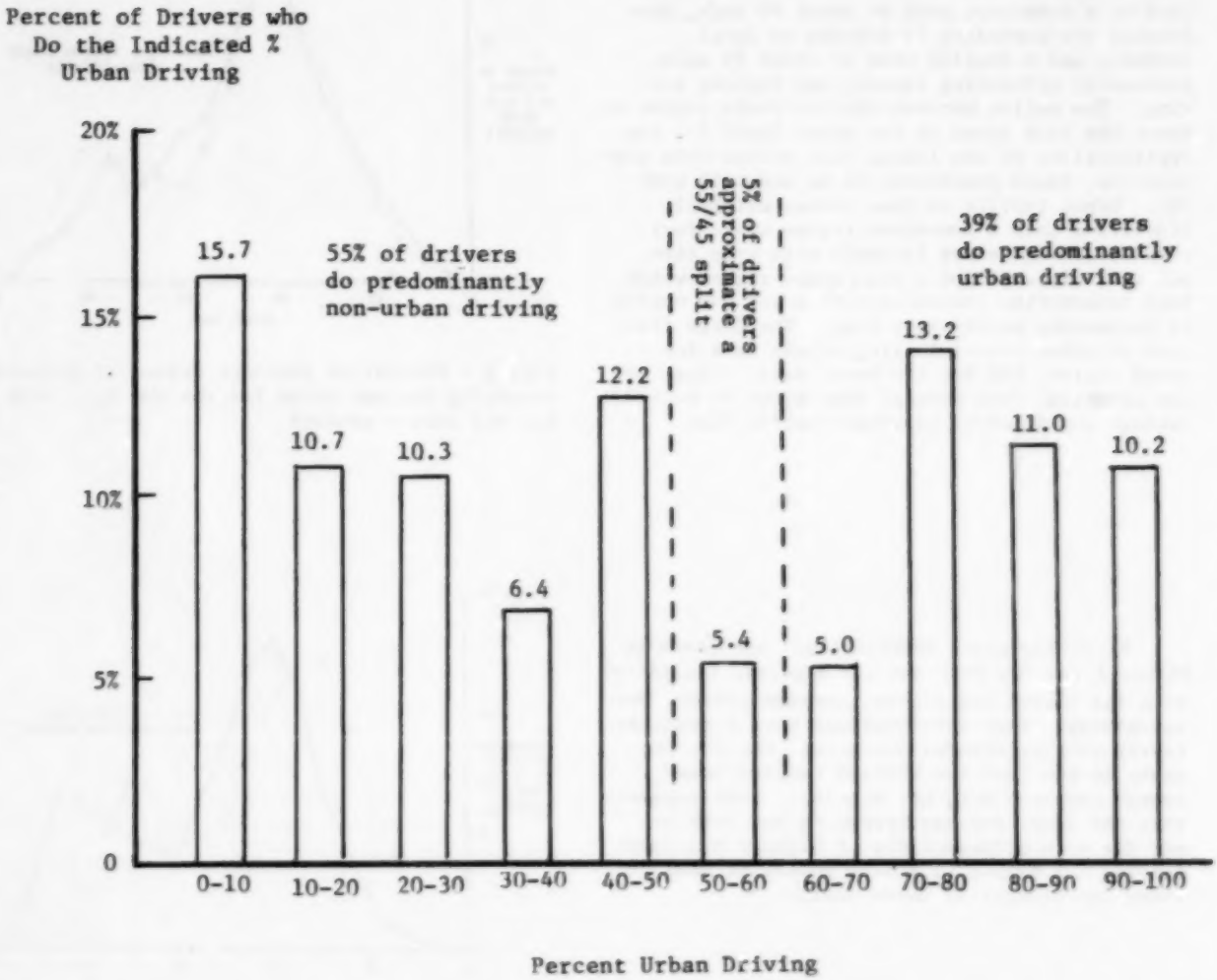


Fig. 2 - Percent of distance driven at indicated microtrip average speed from the Scott Research Data for New York and Los Angeles

Source: P. Wasielewski, et al, "Automobile Braking Energy, Acceleration and Speed in City Traffic", SAE Paper 800795, June 1980.

Figure 2



Source: From data from the DOE/J.D. Power Survey as furnished by Energy and Environmental Analysis, Inc.; sample size ≈ 10,000.

APPENDIX F

N/V Sensitivity Regression Analysis

Regression Equation : $S_{City}^{N/V} = 0.803 - 0.0274\ \overline{N/V}$

Examples : $S_{City}^{N/V}\ (\overline{N/V} = 30) = -0.019$

$S_{City}^{N/V}\ (\overline{N/V} = 60) = -0.841$

Regression Equation : $S_{hwy}^{N/V} = 0.385 - 0.0238\ \overline{N/V}$

Examples : $S_{hwy}^{N/V}\ (\overline{N/V} = 30) = -0.329$

$S_{hwy}^{N/V}\ (\overline{N/V} = 60) = -1.043$